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WATER SUPPLY AND WATER QUALITY CONTROL STUDY, AQUILLA CREEK WATERSHED, LOWER BRAZOS RIVER SYSTEM, TEXAS. STUDY OF NEEDS AND VALUE OF STORAGE FOR MUNICIPAL AND INDUSTRIAL WATER SUPPLY AND WATER QUALITY CONTROL

Public Health Service
Dallas, Texas

October 1965

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WATER SUPPLY AND WATER QUALITY CONTROL STUDY AQUILLA CREEK WATERSHED LOWER BRAZOS RIVER SYSTEM TEXAS

Study of Needs and Value of Storage for Municipal and Industrial Water Supply and Water Quality Control

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Dallas, Texas
OCTOBER 1965

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WATER SUPPLY

AND

WATER QUALITY CONTROL STUDY

AQUILLA CREEK WATERSHED

LOWER BRAZOS RIVER SYSTEM

TEXAS

Abstract

An investigation has been carried out which discloses the need for and value of storage for municipal and industrial water supply purposes in the proposed Aquilla Creek Reservoir on Aquilla Creek. A portion of the future needs for water in the study area can be satisfied from storage in this project. The investigation further found that there is no need for storage for water quality control in the proposed reservoir. Economic and demographic studies revealed a potential for increased industrial development and population growth, and serve as the foundation for the projected needs.

Prepared for

DEPARTMENT OF THE ARMY

U.S. Army Engineer District

Fort Worth, Texas

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

OCTOBER 1965

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I-1

I. INTRODUCTION

Request and Authority

The U.S. Army Engineer District, Fort Worth, in a letter dated December 9, 1964, requested studies of the Aquilla Creek watershed ". . . to determine the municipal and industrial water requirements, the quality of water, the extent of existing and potential pollution, as well as the need for and the benefits from conservation storage for purposes of municipal and industrial water supply and water quality control. . . ."

This study has been made in accordance with (1) A Memorandum of Agreement between the Department of the Army and the Department of Health, Education, and Welfare, dated November 4, 1958, and (2) The Federal Water Pollution Control Act, as amended (33 USC 466 et seq.).

Purpose and Scope

The purpose of this study is to estimate the water requirements for municipal and industrial water supply, and water quality control purposes to the years 2025 and 2075 in the Aquilla Creek watershed. Estimates are made of the value of benefits attributable to the storage of water for these purposes in the Federally proposed Aquilla Creek Reservoir project. This area is also covered in a companion report,"Water Supply and Water Quality Control Study, Navasota River Watershed, Lower Brazos River System, Texas," issued by this office in June 1965. 1/

Acknowledgments

The cooperation of many persons and agencies is gratefully acknowledged. Special appreciation is expressed to the following:

U.S. Army Engineer District, Fort Worth, Texas
U.S. Geological Survey, Austin, Texas
Texas State Department of Health, Austin, Texas
Texas Water Commission, Austin, Texas
Brazos River Authority, Waco, Texas
Officials of cities in the study area

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1. The U.S. Army Engineer District, Fort Worth, is considering the development of the Aquilla Creek watershed, Texas, through the construction of the multiple-purpose Aquilla Creek Reservoir at mile 20.66 on Aquilla Creek.

2. The study area comprises Falls, Hill, and McLennan Counties in central Texas.

3. These 3 counties had a total population of about 195,000 in 1960. Of this total, 135,000 were classified as urban, and 60,000 as rural.

4. Except for the Standard Metropolitan Statistical Area (SMSA) of Waco (McLennan County), the area is generally rural in character.

5. The study area is in a period of rapid economic expansion, as evidenced by the highly diversified manufacturing complex of Waco.

6. Present municipal and industrial water use in the study area is about 23 million gallons per day (mgd).

7. The major water-using industry in the study area is food and kindred products processing. Other major uses are irrigation and recreation.

8. There is one existing reservoir (Whitney) and one reservoir (Waco) under construction with conservation capacities greater than 5,000 acre-feet in the study area. The aggregate conservation and power storage of these reservoirs is 566,000 acre-feet. Reported ground water pumpage in 1958 amounted to almost 18,000 acre-feet.

9. Current inventories show that there are 20 municipal and industrial waste treatment plants in operation in the study area. In general, these plants provide secondary treatment and are operating efficiently within their design capabilities.

10. The organic quality of the water of the Aquilla Creek watershed can be described as good.

Conclusions

1. The study area's population is expected to reach 513,000 by the year 2025, and 771,000 by the year 2075. The urban segment of these totals is 480,000 and 751,000 in 2025 and 2075, respectively. Similarly, the rural portion of the population is expected to be 33,000 in 2025, and 20,000 in 2075.

2. Estimated future municipal, industrial, and rural water supply needs for the Aquilla Creek watershed area are 4.5 mgd in the year 2025 and 9,1 mgd in the year 2075.

3. With the water supply plan as presented herein, the potential water resources of the Aquilla Creek watershed are sufficient to satisfy municipal, industrial, and rural water requirements of the watershed throughout the time horizon of the study (2075). Projected irrigation needs to this time will also be satisfied.

4. The future organic quality of Aquilla Creek watershed waters is expected to remain satisfactory for municipal, industrial, recreational, fish and wildlife, and agricultural uses.

5. Concentrations of total dissolved solids in Aquilla Creek Reservoir can be expected to exceed 500 milligrams per liter (mg/l) for short periods, approximately once in 9 years.

6. No storage for water quality control purposes is required in Aquilla Creek Reservoir.

7. Minimum annual value of benefits of storage for water supply in Aquilla Creek Reservoir based on the most reasonable alternative cost is $158,000. The year of first need is 1975, which is considered "present" for purposes of benefit calculations; therefore, no discounting has been used.

III. PROJECT DESCRIPTION

Pertinent Project Data

The development plan for Aquilla Creek under consideration by the Corps of Engineers provides for the construction of a multiple-purpose reservoir at mile 20.66.

The location of the reservoir site is shown in figure III-1, located at the back of this report, and more specific pertinent data for the plan being considered are shown in table III-1.

Table III-1

Pertinent Data
Aquilla Creek Reservoir

Dam Location	Mile 20.66
Contributing Drainage Area	294 Square Miles
Conservation Storage	59,700 acre-feet
Sediment Storage	28,100 acre-feet
Dependable Yield	9.7 mgd
Approximate depth to top of conservation pool at dam	60 feet

Source: Corps of Engineers 2/

IV. STUDY AREA DESCRIPTION

Location and Boundaries

The study area comprises Falls, Hill, and McLennan Counties in central Texas, (see figure III-1).

The study area chosen is the same as Subarea 1 in the "Water Supply and Water Quality Control Study, Navasota River Watershed, Lower Brazos River System, Texas," 1/ which covers the entire lower Brazos River basin utilizing a single integrated plan of development for both surface and ground water resources. This study is primarily concerned with water resource development in the Aquilla Creek watershed.

Geography and Topography

The study area lies in two physiographic provinces. The eastern portion of the area is in the Gulf Coastal Plain section of the Coastal Plains Province, while the western portion is in the central Texas section of the Great Plains Province.

In the central Texas section part, Cretaceous rocks dip eastward toward the Gulf of Mexico, plateau remnants with undulating to rolling surfaces form interstream divides, and the deeply entrenched streams are bordered by rough hillsides and valleys.

The terrain of that portion of the area in the West Gulf Coastal Plain can be described as level to gentle rolling.

Climate

The study area is characterized by a mild and fairly uniform climate. The mean annual temperature is about 66 degrees, and the normal annual rainfall is about 36 inches. 3/ The average length of the growing season is 241 days. 3/

Principal Communities and Industries

The principal communities of the study area are Waco, West, and McGregor in McLennan County; Hillsboro in Hill County; and Marlin in Falls County. Major manufacturing industries include rubber tires, building materials, glass containers, apparel, and rocket fuel. In addition, agriculture is very important to the areas' economy.

V. WATER RESOURCES OF THE STUDY AREA

Ground Water

The study area includes parts of two physiographic sections - primarily, the West Gulf Coastal Plain section of the Coastal Plain Province and, to a lesser extent, the central Texas section of the Great Plains Province.

Principal aquifers in the study area are the Trinity group, and the Quaternary alluvium.

Quantity of Water Available

Present ground water withdrawal in the study area is 16.0 mgd. 4 5/ The ground water that is potentially available for municipal and industrial, thermal power generation, irrigation, and rural use throughout the study area was evaluated as 25.1 mgd. 4/ A similar figure for the Aquilla Creek watershed is 3.8 mgd. 4/

Quality of Water Available

The chemical quality of ground water differs throughout each aquifer as well as in different aquifers. Analysis of the water from selected wells in the principal aquifers in the basin is given in table V-1. The extremes and the mean were evaluated from only a portion of the total number of analyses on record, but they were considered as representative of the quality of the water in the aquifer. In general, the chemical quality of ground water in the principal aquifers is such that with proper treatment, the water is acceptable for most municipal and industrial water supply purposes.

The public water supplies of many communities are obtained from the Trinity sands, although the concentrations of dissolved solids, and sulfates in some of the wells exceed the maximum limits of the U.S. Public Health Service Standards. The water is suitable for most types of industries, but high concentrations of sodium bicarbonate may be undesirable in boiler and laundry operations. Generally, the Trinity sands yield water that is suitable for irrigation. 5/

The quality of the water from wells in the alluvium along the Brazos River varies greatly, as shown by the following range of concentrations; dissolved solids, 483 to 1,101 mg/l, hardness, 312 to 1,360 mg/l, chloride, 16 to 880 mg/l, specific conductance, 825 to 4,020 micromhos per centimeter. No public water supplies are obtained from the alluvium in the study area.

Table V-1

Characteristic Analysis of Ground Water from the Principal Aquifers in the Aquilla Creek Study Area

Characteristic	Trinity Sands Concentration (mg/l) Max.	Min.	Mean	Alluvium Concentration (mg/l) Max.	Min.	Mean
Silica (SiO_2)	*	*	*	19	16	18
Iron (Fe)	0.08	0.01	0.04	*	*	*
Calcium (Ca)	270	3	92	320	56	158
Magnesium (Mg)	42	1	15	136	7	55
Sodium & Potassium (Na & K)	1420	213	715	384	50	159
Bicarbonate (HCO_3)	444	209	339	574	318	464
Sulfate (SO_4)	3320	75	1159	473	43	178
Chloride (Cl)	214	50	105	880	16	267
Fluoride (F)	0.9	0.8	0.8	0.5	0.1	0.3
Nitrate (NO_3)	1.1	0.0	0.4	76	>1	35
Dissolved Solids	5370	594	2192	2500	483	1101
Hardness (as $CaCO_3$)	846	10	289	1360	312	621
Specific Conductance (micromhos @ 25°C)	990	988	989	4020	825	1781
pH (pH units)	8.1	8.0	8.0	7.7	7.0	7.3

*Data not available.

Source: Texas Water Commission 5/

Table V-2 shows the range and mean values of chemical constituents of the ground water from municipal wells in the Aquilla Creek watershed. Some of these concentrations exceed the maximum limits of the U.S. Public Health Service Drinking Water Standards. The high fluoride concentrations found in some wells is tempered by blending the waters from several wells.

Table V-2

Characteristic Analysis of Water from Municipal Wells in the Aquilla Creek Watershed

Item	Concentration (mg/l) Maximum	Minimum	Average
Iron (Fe)	2.5	0.1	1.1
Calcium (Ca)	37	2	10
Magnesium (Mg)	19	1	5
Sodium (Na)	464	232	321
Sulfate (SO_4)	67.0	65	288
Chloride (Cl)	75	28	50
Fluoride (F)	5.0	0.4	1.5
Nitrate (NO_3)	5.1	0.4	1.1
Total Hardness (as $CaCO_3$)	171	9	44
Total Dissolved Solids (Residue at 105°C)	1,424	660	948
pH (in pH units)	8.5	8.0	8.2

Source: Texas State Department of Health 6/

Surface Water

Quantity of Water Available

There are no existing reservoirs in the Aquilla Creek watershed. The proposed Aquilla Creek project will have a total dependable yield of 9.7 mgd. 2/

Other reservoirs in the study area include Whitney and Waco which are existing and under construction, respectively. The aggregate, dependable yield of these two reservoirs is 358.9 mgd. 2/

Quality of Water Available

The expected dissolved solids concentrations of the principal reservoirs in the study area are shown in table V-3. The concentrations were estimated applying the relationship of the quantity of runoff and total dissolved solids concentration for the drainage area of the study reservoir. Using reservoir operation data furnished by the Corps of Engineers, periodic concentrations in the reservoir were

determined. In this manner, a total dissolved solids concentration of each reservoir was evaluated. For the Aquilla Creek Reservoir, it is estimated that total dissolved solids concentrations can be expected to exceed 500 mg/l for short periods, approximately once in 9 years. This is based on data obtained from two months of intensive sampling of Aquilla Creek for this study by the U. S. Geological Survey at the request of the Texas Water Commission.

Table V-3

Estimated Total Dissolved Solids Concentration in Principal Reservoirs in the Study Area (50%, 80%, and 98% Low Flow Basis)

Reservoir	Total Dissolved Solids Concentration (mg/l) 50%	80%	98%
Waco	255	263	350
Whitney	870	870	870
Aquilla Creek	350	440	760

Mean values of total dissolved solids, chlorides, and sulfates of four streamflow sampling stations located in the study area are shown in table V-4.

Table V-4

Characteristic Analysis of Streamflow in the Study Area

Location of Sampling Station	Characteristic (mg/l) No. of Samples	Total Dissolved Solids	Sulfates	Chlorides
Brazos River at Whitney Dam near Whitney	a/	851	175	260
Aquilla Creek near Aquilla	b/	393	134	28
Brazos River at Waco	1	1,240	325	450
Brazos River near Marlin	33	808c/	204	296

a/ Continuous sampling from September 9, 1947 through May 16, 1948, and from October 1948 through September 1961.
b/ Continuous sampling from May 1, 1965 through June 25, 1965.
c/ 31 samples.

Source: Texas State Department of Health 7/, Texas Water Commission 8/, and Geological Survey 9/

VI. THE ECONOMY

An economic study and projections were made of the study area and the Aquilla Creek watershed. These projections serve as a basis for estimating future municipal and industrial water use requirements and anticipated waste discharges.

Present

Main cities in the study area are Waco and its suburbs, West, Hillsboro, Marlin, and McGregor. Hillsboro is the largest city in the watershed. Study area population increased from 162,450 in 1920 to 195,004 in 1960, [10] with most of the growth occurring in the Waco SMSA.

Manufacturing is an important segment of the study area economy with manufacturing accounting for 16 percent of the 1960 labor force. [11] The principal items of manufacture in the study area are rubber tires and innertubes, doors, windows, glass containers, and apparel in Waco, asbestos cement products in Hillsboro, and the production of rocket fuel in McGregor. [12]

Agriculture is relatively important in the study area, accounting for 10 percent of the 1960 labor force. [11] The 1959 value of farm products sold was $41 million, [13] about equally distributed between crops and livestock. Cotton is the major crop grown. Corn, oats, grain sorghums, and vegetables are also produced. Livestock production is diversified with cattle, dairy, poultry, and hogs contributing to the agricultural income. Very little irrigation is done in the study area, with only 8,650 acres irrigated in 1959. [13]

Future

Future growth of the study area is expected to be centered around continued growth and physical expansion of the Waco SMSA. Industry growth is expected to occur in those industries already located in the study area. Projected labor force for 2025 and 2075 is shown in table VI-1.

Table VI-1

Study Area Labor Force, Present and Projected

	1960*		2025		2075	
	Number	Percent	Number	Percent	Number	Percent
Agriculture (Forestry & Fisheries)	7,541	10.6	2,800	1.4	2,800	.9
Mining, Total (SIC 13, 14)	76	.1	150	.1	250	.1
Manufacturing	11,243	15.8	32,450	16.7	52,350	17.5
Resource Oriented	6,983	9.8	19,200	9.9	29,700	9 9
Furn., Lbr., Wood (SIC 24, 25)	1,278	1.9	2,900	1.5	5,200	1.7
Primary Metals (SIC 33)	12	--	250	0.1	550	.2
Food and Kindred (SIC 20)	1,835	2.6	5,900	3.0	8,500	2.8
Chemical & Allied (SIC 28)	309	.4	700	0.4	1,400	.5
Stone, Clay, Glass (SIC 32)	1,442	2.0	3,500	1.8	6,150	2.1
Other Nondurables (SIC 26, 29, 30, 31)	2,107	2.9	5,950	3.1	7,900	2.6
Nonresource Oriented	4,260	6.0	13,250	6.8	22,650	7.6
Fabricated Metal (SIC 34, 35, 36, 37, 38)	1,329	1.9	5,700	2.9	9,400	3.1
Textiles (SIC 22, 23)	2,037	2.9	6,400	3.3	11,700	3.9
Print., Publ., NEC (SIC 27, 39)	894	1.2	1,150	0.6	1,550	.6
Service and Other	48,745	68.6	151,360	77.8	232,600	77.5
Unemployed	3,474	4.9	7,740	4.0	12,000	4.0
Total Labor Force	71,079	100.0	194,500	100.0	300,000	100.0

*Source: Bureau of the Census 11/

Based on a resource and employment analysis, the study area population was determined. A portion of this population was then allocated to the Aquilla Creek watershed. The watershed area, located adjacent to both the Fort Worth and Waco SMSA, is expected to grow mainly as a result of expansion of these metropolitan areas. Projections of populations for the study area and the watershed appear in table VI-2.

Table VI-2

Population Projections for the Study Area and Watershed
1960, 2025, 2075
(1,000's)

Study Area

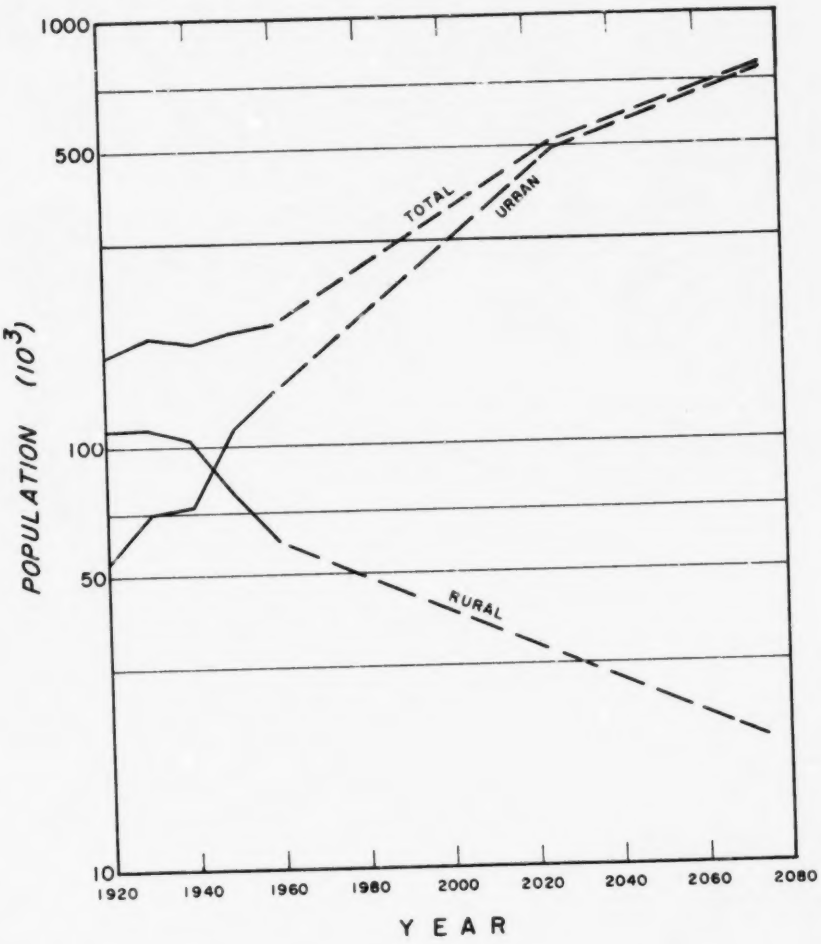
Year	Urban	Rural	Total
1960	135.0	60.0	195.0
2025	480.0	33.0	513.0
2075	751.0	20.0	771.0

Aquilla Creek Watershed

1960*	7.5	8.0	15.5
2025	21.5	2.5	24.0
2075	37.5	2.5	40.0

*Estimated.

A graphical presentation of the study area population projections is shown in figure VI-1.



WATER SUPPLY & WATER QUALITY CONTROL STUDY
AQUILLA CREEK WATERSHED
BRAZOS RIVER BASIN, TEXAS

STUDY AREA POPULATION TRENDS AND PROJECTIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE VI-1

VII. WATER REQUIREMENTS

General

The term water requirements encompasses several uses which are dependent upon a large number of variables. Although primarily concerned with water requirements for municipal, industrial, and water quality control purposes, this study examines all of the consumptive uses of water as they affect the supply and demand for water within the basin.

Types of Water Use

Municipal

Municipal water as defined here includes residential, commercial, public, and those industrial uses which can reasonably be reflected in a per capita use figure. Also included in the per capita quantities are losses in distribution systems and treatment plant attentuation.

Industrial

The definition of industrial water use in this study refers to all water except that supplied from municipal systems which is used by the manufacturing industries (Standard Industrial Classification Categories 13, 14, and 20 through 39). 14/

Power Generation

Use of water for thermal power generation is a part of the industrial requirement that has been determined separately. Although withdrawal for this purpose is very large, only the water used consumptively is considered.

Rural

An estimate of the rural water use was made so as not to understate the total study area water requirements. As referred to in this investigation, rural water requirements are assumed to consist of domestic water for that portion of the population not served by municipal water systems and water for the maintenance of livestock.

Irrigation

Another important water use in the study area is irrigation. These requirements are included, since (1) return flows from this use affect the quality of the study area's water and (2) a fully integrated water supply plan must include irrigation, especially

in an area where it represents a considerable portion of the demand on the potential water resource. Historic as well as projected quantities of water for this use were determined by the Corps of Engineers, based on U. S. Study Commission, Texas values. 2/

Base Year Water Use

The year 1958 was selected as the base for the water use study because it was the most recent year for which reliable data from several sources were available. The 1958 study area water use by type is shown in table VII-1.

Table VII-1

Study Area Base Year Water Use

Type of Use	1958 (mgd)
Municipal	19.4
Industrial*	3.8
Rural	6.0
Irrigation	6.0
Total	35.2

*Includes consumptive use for thermal power generation.

Source: Public Health Service 15/, Texas Board of Water Engineers 16-18/, University of Texas 19/, and Bureau of the Census 20/

Similar estimates for the Aquilla Creek watershed are shown in table VII-2.

Table VII-2

Aquilla Creek Watershed Base Year Water Use

Type of Use	1958 (mgd)
Municipal	1.6
Industrial*	Negligible
Rural	0.7
Irrigation	0.1
Total	2.4

*Includes consumptive use for thermal power generation.

Future Water Requirements

Estimates of water requirements for the years 2025 and 2075 for the several types of water use (excluding irrigation) in the study area were made using the technique of combining projected unit uses with economic and population projections. Rural per capita use was assumed to remain constant from 2025 to 2075. Irrigation requirements were furnished by the Corps of Engineers, based on U. S. Study Commission, Texas values. 2/

Municipal

The several items considered in making projections of per capita municipal water use for this study are as follows:

1. Past Trends - analysis of records from municipalities and industries.

2. Characteristics of the subarea - factors peculiar to an area such as per capita income and precipitation.

3. Analysis of projections by others - projections made by other governmental agencies, consulting engineers, and the municipalities themselves.

4. Judgment - after considering and weighing the above factors, discrepancies which existed were resolved by judgment.

Present and projected values of per capita municipal use are shown in table VII-3.

Table VII-3

Municipal Per Capita Water Use
(in gal/day)

1958	2025	2075
121	170	185

Industrial

Base year data on industrial water use were combined with employment data and resulted in a unit water use per employee for each of the industrial categories (SIC 13, 14, and 20-39). Considerations involved in economic projections of the labor force required consolidation of some of the industrial categories into groups, as shown in table VII-4.

In order to project unit industrial water use, the following assumptions were made:

1. In presently undeveloped counties where large future developments are projected, the base year unit employee water uses were adjusted to those of surrounding counties where present conditions approach those forecasted for the undeveloped counties.

2. An average net productivity factor (i.e., the multiplier to obtain unit employee use for the years 2025 and 2075 from 1958 data) was determined as follows: Unit employee industrial water use projections of Resources for the Future, Inc., and the Business and Defense Services Administration prepared for the Senate Select Committee on National Water Resources 21/ were extrapolated and an average curve constructed. The ratio of the 2025 and 2075 values to the 1958 value on the average curve gave the productivity factors of 2.1 and 2.6 for 2025 and 2075, respectively.

Unit industrial water use for all industries in the years 2025 and 2075 is shown in table VII-4.

Power Generation

Consumptive use of water for thermal power generation is considered to be a part of the industrial requirement but is determined separately. Information on future water use was gathered from power companies in the area and combined with data developed by the Federal Power Commission and the Edison Electric Institute for the Senate Select Committee on National Water Resources. Consideration was given to the general locations of future power generation installations and the projected needs apportioned throughout the study area using hypothetical service areas for the several generating plants.

Rural

For purposes of this study, the rural water requirements are assumed to consist of domestic water for that portion of the population not served by municipal water systems and water for the maintenance of livestock. The 2025 and 2075 requirements for rural water are based on a rural per capita use of 180 gallons per day, of which 80 gpcd is for the maintenance of livestock.

Table VII-4

Future Unit Industrial Water Use
(gal. per employee day)

Item	2025	2075
Mining (SIC 13, 14)	50	70
Manufacturing		
Furniture, Lumber & Wood (SIC 24, 25)	190	230
Primary Metals (SIC 33)	1,650	2,040
Food & Kindred (SIC 20)	450	560
Chemicals & Allied Products (SIC 28)	1,050	1,300
Stone, Clay, and Glass Products (SIC 32)	880	1,090
Petroleum (SIC 29)	530	660
Pulp and Paper (SIC 26)	210	280
Other Nondurables (SIC 30, 31)	510	630
Fabricated Metals (SIC 34, 35, 36, 37, 38)	170	210
Textile & Apparel (SIC 22, 23)	160	190
Printing & Publishing and Not Elsewhere Classified (SIC 27, 39)	40	50

The estimated future study area water requirements are shown in table VII-5.

Table VII-5

Future Study Area Water Requirements
(mgd)

Type of Use	Year 2025	Year 2075
Municipal	81.7	139.0
Industrial*	18.1	59.0
Rural	5.9	3.6
Irrigation	122.5	122.5
Total	228.2	324.1

*Includes consumptive use for thermal power generation.

Similar estimates of future water use for the watershed are shown in table VII-6.

Table VII-6

Future Aquilla Creek Watershed Water Requirements
(mgd)

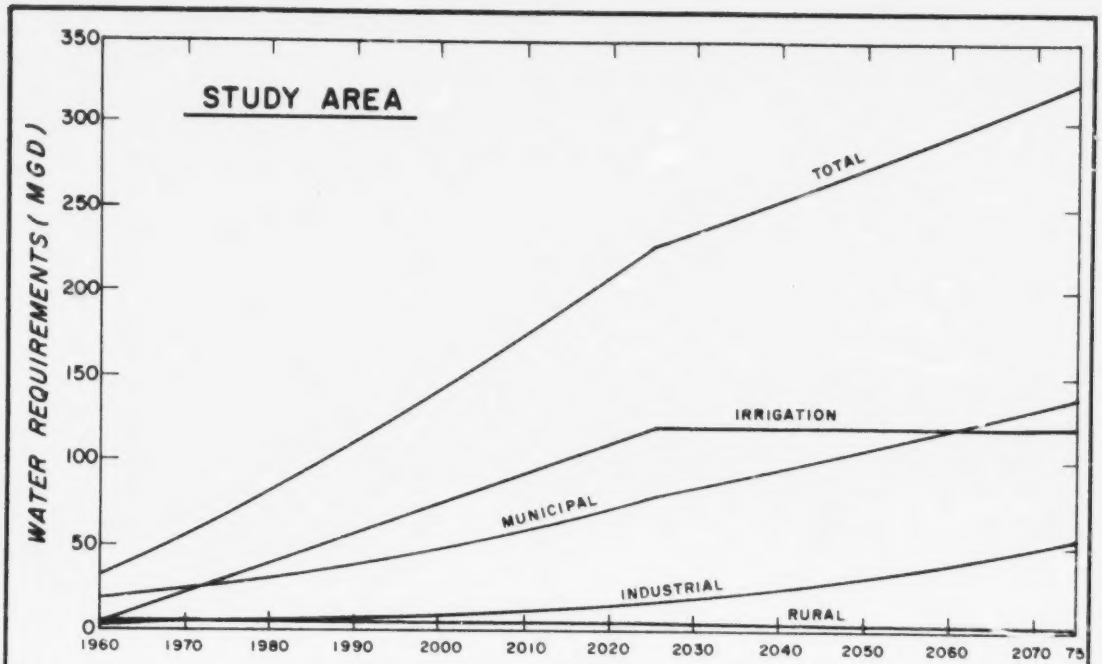
Type of Use	Year 2025	Year 2075
Municipal	3.4	7.0
Industrial*	0.6	1.6
Rural	0.5	0.5
Irrigation	2.9	2.9
Total	7.4	12.0

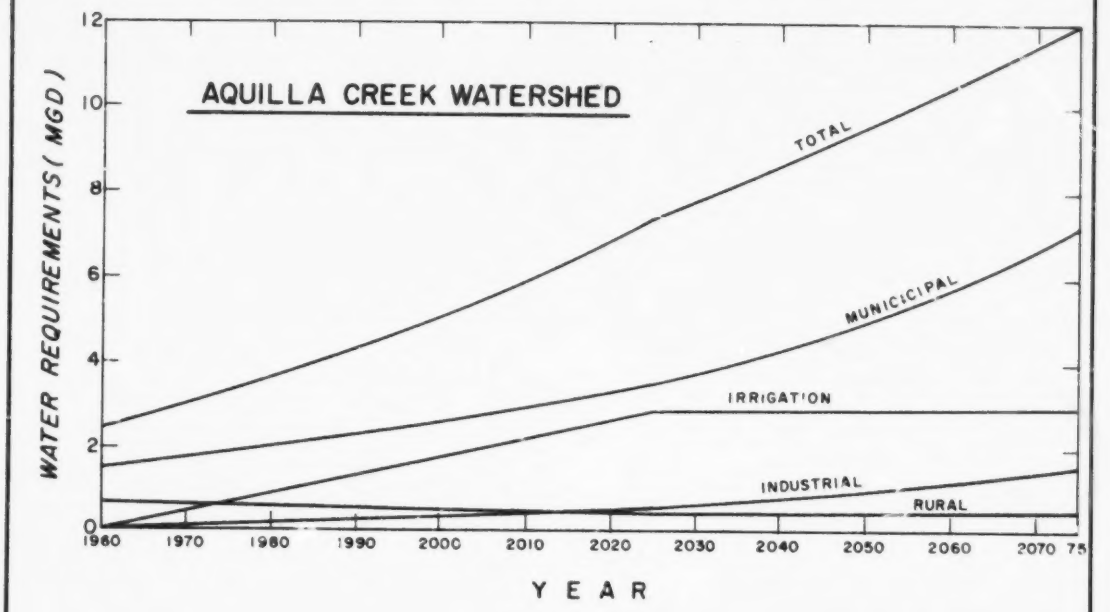
*Includes consumptive use for thermal power generation.

Graphic illustrations of the water requirements for the study area and watershed are shown in figure VII-1.

The city of West, which is outside the Aquilla Creek watershed, is expected to contract for part of the storage in the proposed project. Estimated future municipal and industrial needs for this city are 1.3 mgd in 2025 and 2.7 mgd in 2075.

An examination of historical records indicated that there are no significant seasonal variations in municipal and industrial water use in the study area. It is concluded, therefore that water needs are relatively constant throughout the year and no release schedule of water stored for municipal and industrial use is required.





WATER SUPPLY & WATER QUALITY CONTROL STUDY
AQUILLA CREEK WATERSHED
BRAZOS RIVER BASIN, TEXAS

WATER REQUIREMENTS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE VII-1

VIII. WATER QUALITY CONTROL

General

Water quality control is defined as any measure employed to enhance the utility, value, and attractiveness of waters used for purposes which are affected by changes in water quality. Waters in nature are never PURE in the strict chemical sense of the word. More often than not, however, natural waters are fit for use by man in his pursuit of normal endeavors. This use and subsequent return of waste almost always causes some degradation of water quality downstream, even after provision of secondary waste treatment. As population and the associated demand for water increase, this degradation of the water resource increases. Presently, water quality is controlled by providing the best practical waste treatment. When further water quality improvement is needed, this treatment is supplemented by the provision of additional water to dilute the treated wastes. This, then, is the method of water quality control with which this report is concerned.

Municipal, Industrial, and Agricultural Pollution

Stream Loading

The determination of the quantity and quality of return flows expected to reach a stream is the first step necessary in analyzing water needs for quality control.

The quantity of municipal and industrial return flows is estimated as a percentage of water use. The municipal return flow percentage used is 62.0 percent, 22/ while industrial return flow percentages vary from 23 percent to 90 percent. 23/

The quality of municipal return flow is based on assumed per capita contributions of 0.23 pounds per day of total dissolved solids and 0.25 pounds per day of ultimate first-stage BOD.

The contribution of total dissolved solids resulting from industrial use varies from 1.2 tons per million gallons to 12.2 tons per million gallons of return flow. 23/ For the BOD contribution from industry, it was assumed that final industrial effluents would contain the same concentration of BOD as a municipal sewage that has been treated to remove 85 percent of the BOD. This concentration is 56 mg/l ultimate first-stage BOD assuming a typical municipal sewage has an untreated concentration of 370 mg/l ultimate first-stage BOD.

It was assumed that there would be no return flow resulting from rural water use.

Irrigation return flows were assumed to be one-third of the water applied for that purpose, and it was further assumed that all of the dissolved solids in the irrigation source water would be returned to the stream. 24/

Present and projected study area municipal and industrial return flows, population equivalents, BOD, and total dissolved solids loads are shown in table VIII-1.

Water Quality Criteria

Of the indicators presently available as a measure of water quality, dissolved oxygen and total dissolved solids were chosen for use in this study. The principal causes of pollution in this watershed are (1) domestic sewage and a large variety of industrial wastes, both of which contribute BOD and total dissolved solids; and (2) irrigation return flows which would contribute total dissolved solids. Water quality control requirements are based on the assumption that sufficient waste treatment will be provided for the manmade portion of the pollution to remove 85 percent of the BOD and none of the total dissolved solids.*

Water to regulate quality is assumed to be needed when the dissolved oxygen content of a stream drops below 4 mg/l and/or when the total dissolved solids reach 1,000 mg/l. The lower limit of 4 mg/l of dissolved oxygen was used since (1) it provides an acceptable environment for most aquatic life native to this area; and (2) it provides a buffer zone in the event unforseen spills of waste occur. U. S. Public Health Service Drinking Water Standards 26/ recommend total dissolved solids concentration not exceed 500 mg/l. Although a goal of maintaining total dissolved solids below this figure is desirable, it is not attainable in the watershed; therefore the practical goal of 1,000 mg/l was selected.

Flow Regulation

Allowance for Streamflow

In determining the draft-on-storage required to preserve the quality of the stream, it is necessary to make allowances for natural flows that can be expected to occur in the stream. Discharge frequency analyses of the streams in the basin were made from Corps of Engineers' streamflow data, which included adjustments to reflect conditions in the basin in 2025. Calculations were then performed

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* With conventional treatment methods currently used, removal of some of the total dissolved solids probably occurs; however, this removal can be considered as incidental rather than planned and no reliable estimates of the quantity so removed are available.

Table VIII-1

Present and Projected Study Area
Municipal and Industrial Return Flows and Waste Loads

County	1962*			2025			2075		
	Return Flow (mgd)	P.E. (BOD) Discharged	Total Dissolved Solids Discharged (tons/day)	Return Flow (mgd)	P.E. (BOD) Discharged	Total Dissolved Solids Discharged (tons/day)	Return Flow (mgd)	P.E. (BOD) Discharged	Total Dissolved Solids Discharged (tons/day)
Falls	0.58	3,510	0.99	3.27	4,368	5.56	7.50	9,804	12.53
Hill	0.79	1,370	1.10	3.35	4,620	4.65	7.14	9,144	10.39
McLennan	11.54	16,150	15.44	52.43	70,248	71.05	87.04	112,968	111.98
Total	12.91	21,030	17.53	59.05	79,236	81.26	101.68	131,916	134.90

*Source: Public Health Service 25/

to determine the amount of regulation water from storage needed to maintain stream quality for hydrologic conditions that can be expected to recur in the basin streams every 50 years. This hydrologic condition was used since the downstream use of the water is for municipal and industrial purposes.

Quality Control Requirements

The analyses of the basin waters, one of organic pollution (BOD), and one of chemical pollution (total dissolved solids), were made utilizing electronic computational methods where applicable. These studies were made for the watershed by constructing a mathematical model of the system containing Aquilla Creek Reservoir and points of withdrawal and inflow.

Computations of both organic and inorganic pollution indicated that the surface waters of the watershed will not be degraded below the stated acceptable limits within the time horizon of the study (2075). The city of Hillsboro discharges adequately treated sewage effluent into the proposed Aquilla Creek Reservoir via Hackberry Creek. The quality of the water stored in Aquilla Creek is not expected to be adversely affected by this waste discharge.

Consideration was given to providing storage for water quality control in Aquilla Creek Reservoir to improve the quality of the Brazos River downstream from the confluence of Aquilla Creek. The storage available however, is so small compared to the flows of the Brazos River at this point that no appreciable improvement in quality would result.

IX. WATER SUPPLY AND WATER QUALITY CONTROL PLAN

General

In order to supply the water needs shown in Section VII, a plan is presented utilizing all available water resources in the Aquilla Creek watershed. This plan was incorporated into a single integrated plan for the entire lower Brazos River basin in a companion report. 1/

Water Availability

With the proposed Aquilla Creek Reservoir in operation, the water resources of the Aquilla Creek watershed in the years 2025 and 2075 will be as shown in table IX-1.

Table IX-1

Future Water Resources
of the Aquilla Creek Watershed

Surface:	Dependable Yield (mgd)
Aquilla Creek Reservoir	9.7*
Reusable municipal, industrial, and irrigation return flows - varying quantity 1960 - 2025	0.6 - 2.5
Ground Water	3.8
Total resources in 2025	16.0
Additional resources available after 2025	
Additional reusable municipal, industrial and irrigation return flows - varying quantity 2025 - 2075	
(gross 2.5 - 5.3)	net 0 - 2.8
Total resources in 2075	18.8

*Source: Corps of Engineers 2/

The cities of Hillsboro and West are expected to contract for the conservation storage in Aquilla Creek Reservoir. 2/ The water resources of the watershed therefore will be used to satisfy the total requirements within the confines of the drainage area as shown in figure VII-1, plus the municipal and industrial requirements of the city of West.

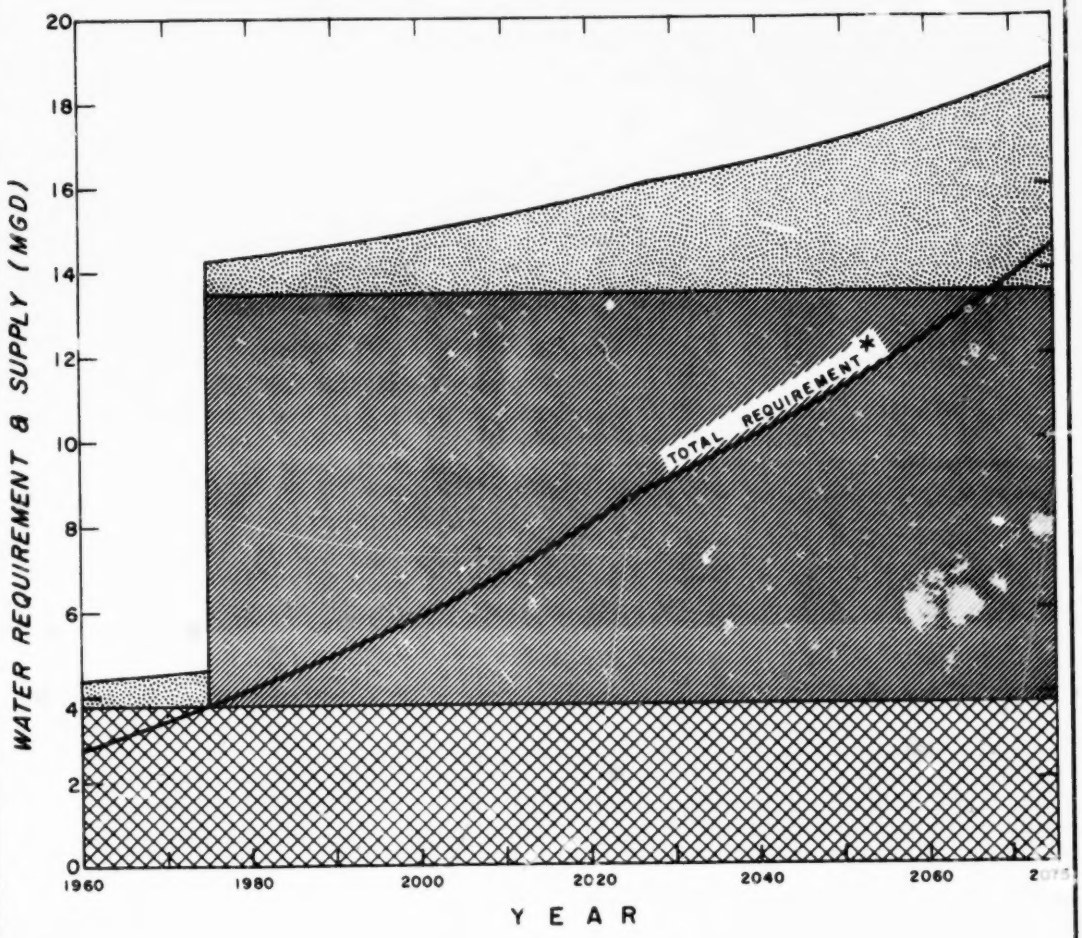
An overplot of the water resources of the watershed on the requirement described above shows that they are adequate to meet requirements through the terminal year of the study (2075). See figure IX-1.

Time of Need

The time of need for the proposed Aquilla Creek Reservoir was determined from the watershed requirement and supply study shown in figure IX-1. This curve shows that there is a need in the Aquilla Creek watershed for the Aquilla Creek Reservoir in the year 1975. Therefore, the benefits for Aquilla Creek Reservoir need not be discounted, since the year 1975 is used as "present" for purposes of benefit calculations.

Alternatives

After consideration of several reservoir sites as well as ground water development, it is concluded that the most likely alternative to the multiple-purpose development in the Aquilla Creek watershed is a single-purpose, two stage development near the same location.



LEGEND

- GROUNDWATER DEVELOPMENT
- AQUILLA CREEK RESERVOIR
- REUSEABLE RETURN FLOW

*INCLUDES ALL REQUIREMENTS IN THE AQUILLA CREEK WATERSHED AND INDUSTRIAL AND MUNICIPAL REQUIREMENTS FOR THE CITY OF WEST.

WATER SUPPLY & WATER QUALITY CONTROL STUDY
AQUILLA CREEK WATERSHED
BRAZOS RIVER BASIN, TEXAS

WATER REQUIREMENT AND SUPPLY

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE IX-1

X. BENEFITS

Method of Evaluation

Senate Document No. 97 (87th Congress 2nd session) makes the following statement concerning evaluation of benefits of municipal and industrial water supply storage in Federal reservoirs:

> "The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project."

This alternative cost method was used to evaluate storage requirements for municipal and industrial use in the multiple-purpose reservoir project proposed to be developed in the Aquilla Creek watershed. The values determined in this way are considered to be minimum annual benefits.

Costs

For purposes of comparison of alternatives, capital costs were converted to equivalent annual costs and added to the estimated annual operation and maintenance costs. The costs were determined for the date of first use of the project and, when necessary, discounted to "present" 1975 values.

Water Supply Benefits

The annual project water supply benefit is $158,000. The methods of calculation used for the benefit evaluation are appended. The above value represents present worth in 1975.

XI. BIBLIOGRAPHY

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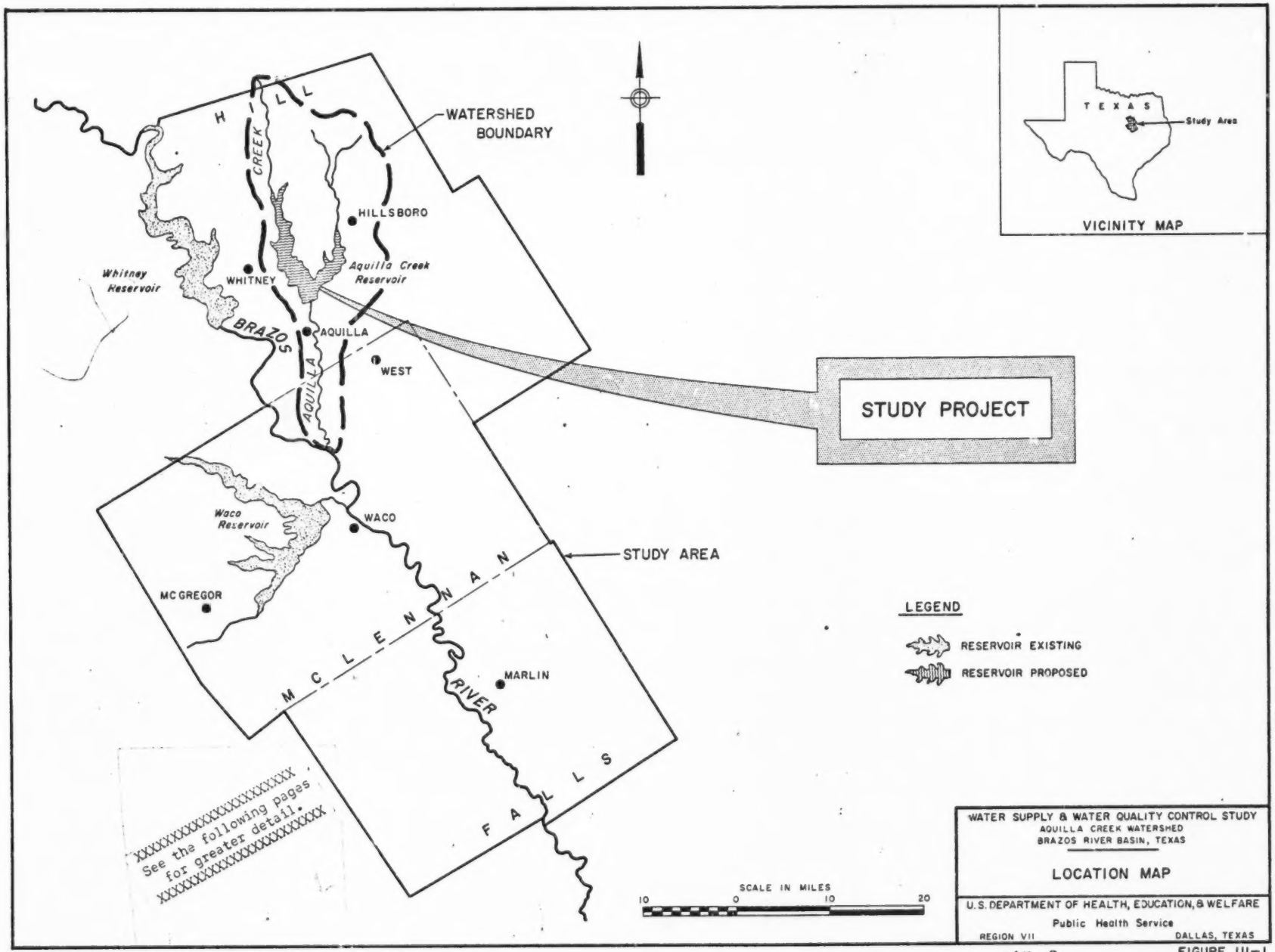

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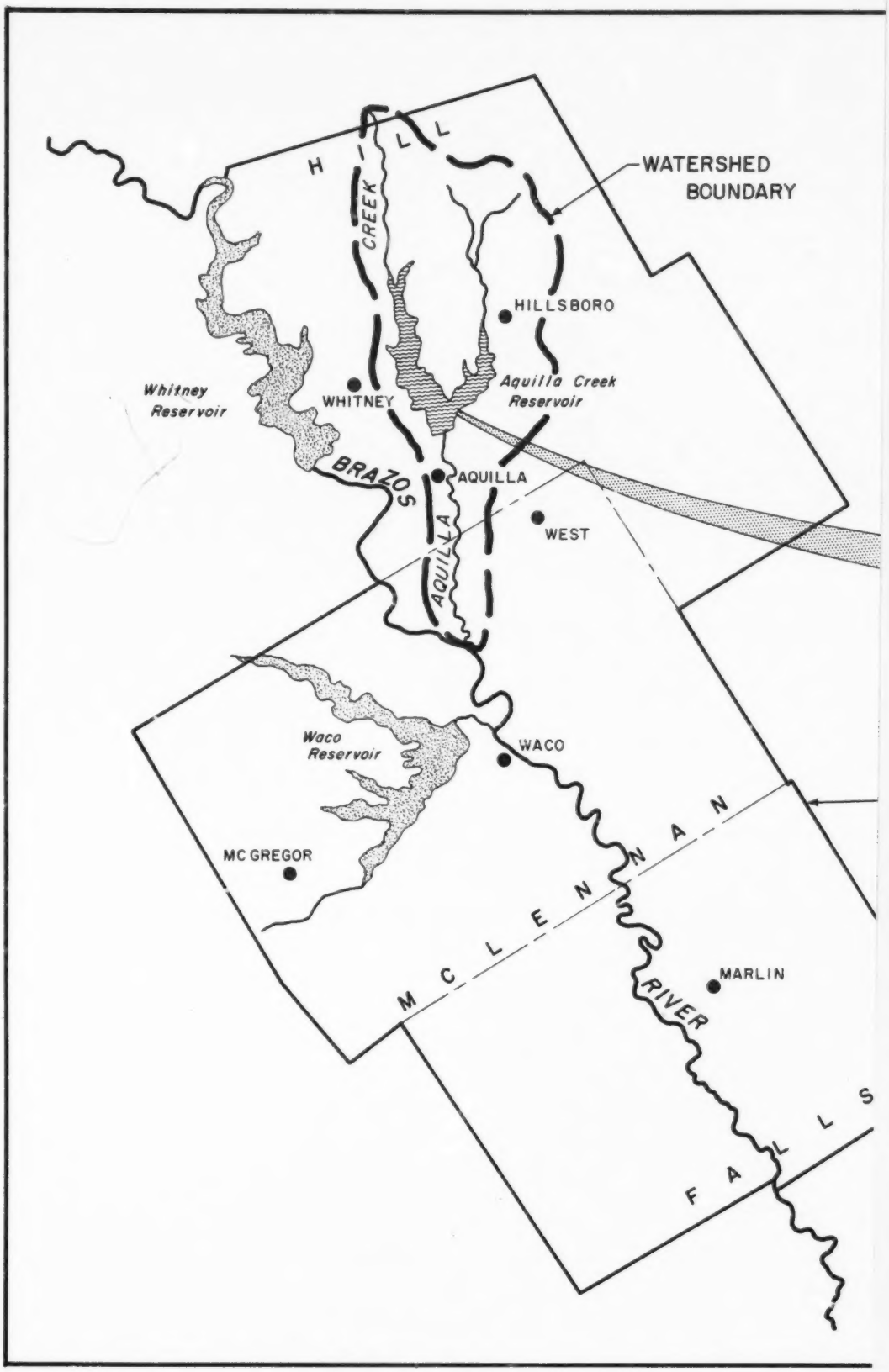
See tha following pages
for greater detail.
XXXXXXXXXXXXXXXXXXX

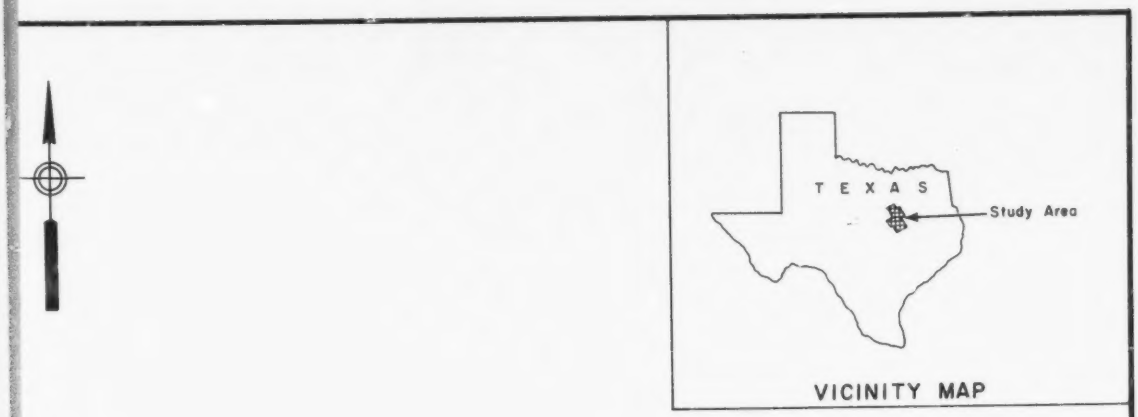
WATER SUPPLY & WATER QUALITY CONTROL STUDY
AQUILLA CREEK WATERSHED
BRAZOS RIVER BASIN, TEXAS

LOCATION MAP

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE III-1


HILL
CREEK
WATERSHED
BOUNDARY
HILLSBORO
Whitney
Reservoir
WHITNEY
Aquilla Creek
Reservoir
BRAZOS
AQUILLA
AQUILLA
WEST
Waco
Reservoir
WACO
MC GREGOR
MCLENNAN
RIVER
MARLIN
FALLS



VICINITY MAP

STUDY PROJECT

STUDY AREA

LEGEND

RESERVOIR EXISTING

RESERVOIR PROPOSED

SCALE IN MILES

10 0 10 20

WATER SUPPLY & WATER QUALITY CONTROL STUDY
AQUILLA CREEK WATERSHED
BRAZOS RIVER BASIN, TEXAS

LOCATION MAP

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE III-1

APPENDIX - H

Benefit Calculations

The most reasonable alternative to the proposed Aquilla Creek Reservoir is two smaller single-purpose reservoirs near the project site having a total yield equal to the multiple-purpose project and constructed in step with water needs.

Dependable yield of Aquilla Creek project = 9.7 mgd

From Figure IX-1:

Build first reservoir in 1975; yield = 5.0 mgd

Build second reservoir in 2025; yield = 4.7 mgd

First Unit - 5.0 mgd dependable yield

Estimated first cost	$3,100,000
Estimated interest during construction	124,000
Estimated total investment	$3,224,000

Amortize private investment for 25 years @ 4%

(3,224,000)(.06401) = $206,368/year

Convert to equivalent Federal investment to provide for same annual payment

Present worth of 1 per period @ 3 1/8% = 17.17308

Then equivalent Federal investment

(206,368)(17.17308) = $3,543,974

Amortize Federal investment for 100 years at 3 1/8%

Annual cost = (3,543,974)(0.03276)	=	116,100
Estimated annual operation and maintenance	=	15,000
Total Annual Cost	=	131,100

Date of first use is 1975, therefore no discounting of benefits is necessary.

Annual value of benefits for first unit = $ 131,100

Second Unit - 4.7 mgd dependable yield

Estimated first cost	=	$2,950,000
Estimated interest during construction	=	118,000
Estimated total investment	=	$3,068,000

Amortize private investment for 25 years @ 4%

(3,068,000)(.06401)	=	$ 196,383/yr.

Convert to equivalent Federal investment to provide for same annual payment

Present worth of 1 per period @ 3 1/8%	=	17.17308

Then equivalent Federal investment

(196,383)(17.17308)	=	$3,372,500

Amortize Federal investment for 100 years at 3 1/8%

Annual cost = (3,372,500)(0.03276)	=	$ 110,483
Estimated annual operation & maintenance	=	15,000
Total annual cost	=	$ 125,483

Date of first use is the year 2025, therefore discount estimate to present (1975)

(125,483)(0.214685)	=	$ 26,939
Say	=	$ 26,900

Therefore, annual value of benefits for second unit = $ 26,900

Total annual value of benefits - first unit plus second unit

$131,100 + $26,900 = $158,000

Therefore annual value of benefits = $ 158,000